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(54) **CONTROL CIRCUIT FOR BALANCING CURRENT AND METHOD THEREOF**

(75) Inventors: **Pei-Ting Chen**, Chunan (TW); **Chih-Tsan Huang**, Chunan (TW); **Tzu-Shou Kuo**, Hsinchu (TW)

(73) Assignees: **Coretronic Corporation**, Miaoli County (TW); **Young Lighting Technology Corporation**, Hsinchu (TW)

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G09G 3/30 (2006.01)

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(58) **Field of Classification Search** 345/30, 345/39, 52, 63, 77, 82, 204, 214, 690
See application file for complete search history.

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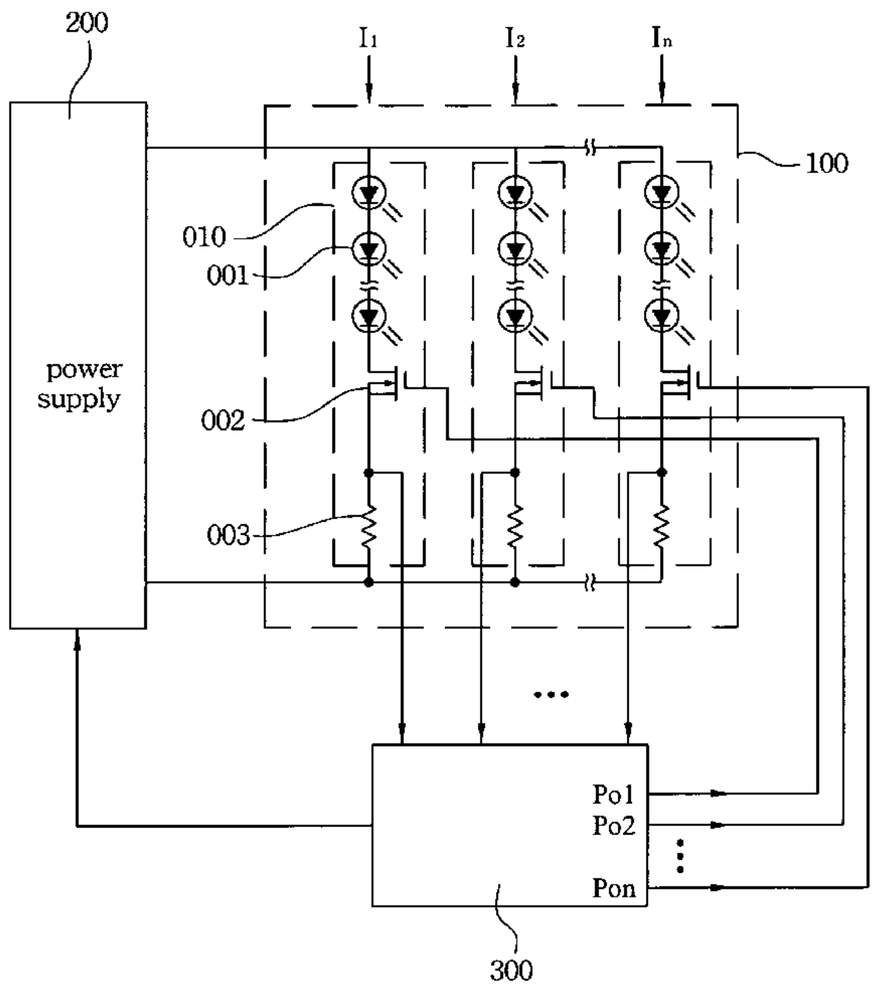
Primary Examiner—Bipin Shalwala
Assistant Examiner—Vince E Kovalick
(74) *Attorney, Agent, or Firm*—Rosenberg, Klein & Lee

(57) **ABSTRACT**

A control circuit for balancing current in a thin display device includes a light source, a power supply, and a control part. The light source includes a plurality of parallel light-emitting diode (LED) rows. The LED row includes at least one LED and a switch unit. The switch unit is in series connection with the LED. The switch unit has two working conditions, one is on and the other is off, to determine whether the current passes through the LED row. The power supply provides a working power for the LEDs. The control part detects the currents of the LED rows, controls the on-state timing ratio of the switch unit and controls the output power of the power supply.

9 Claims, 6 Drawing Sheets



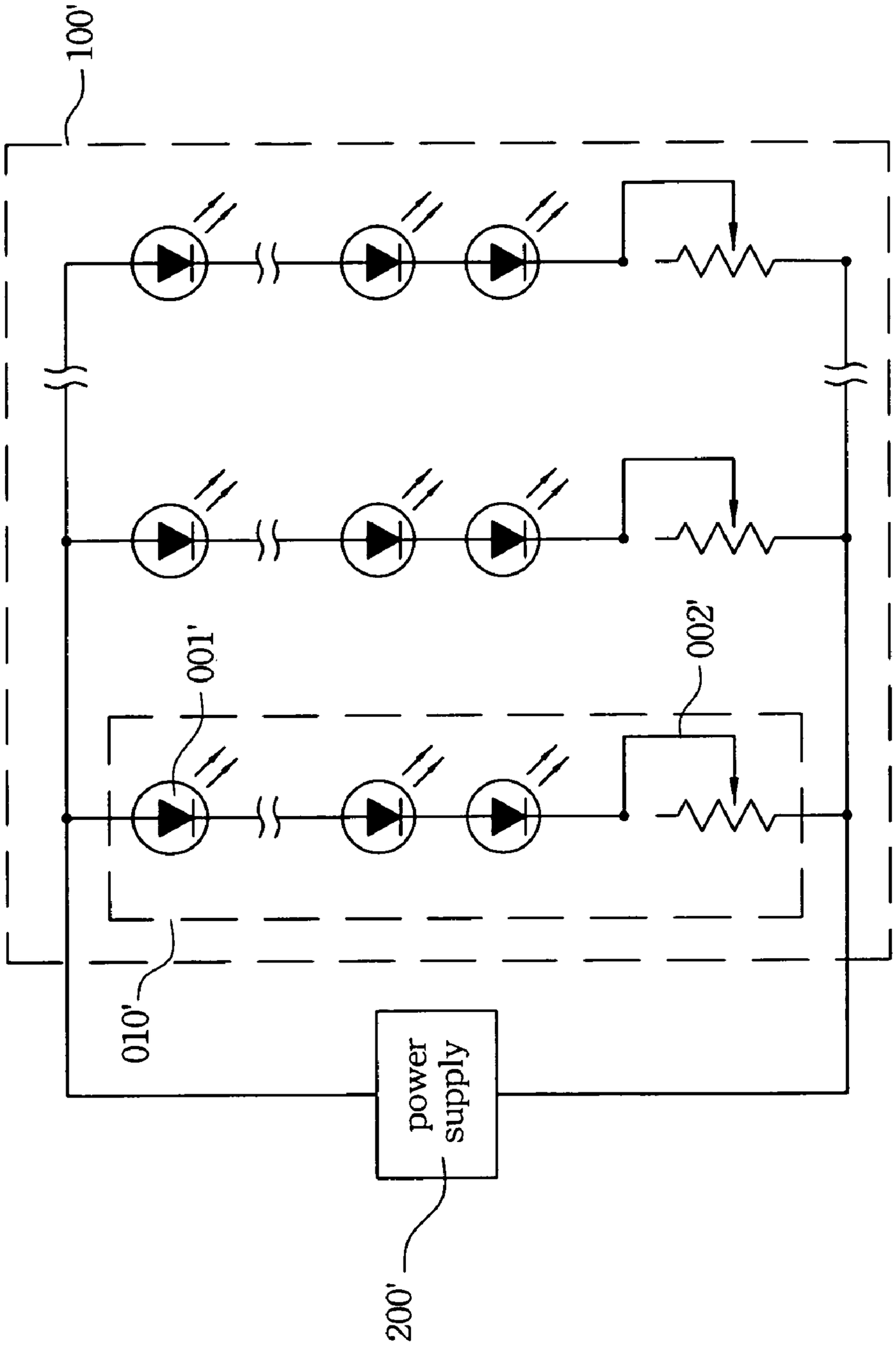


FIG. 1
(Prior Art)

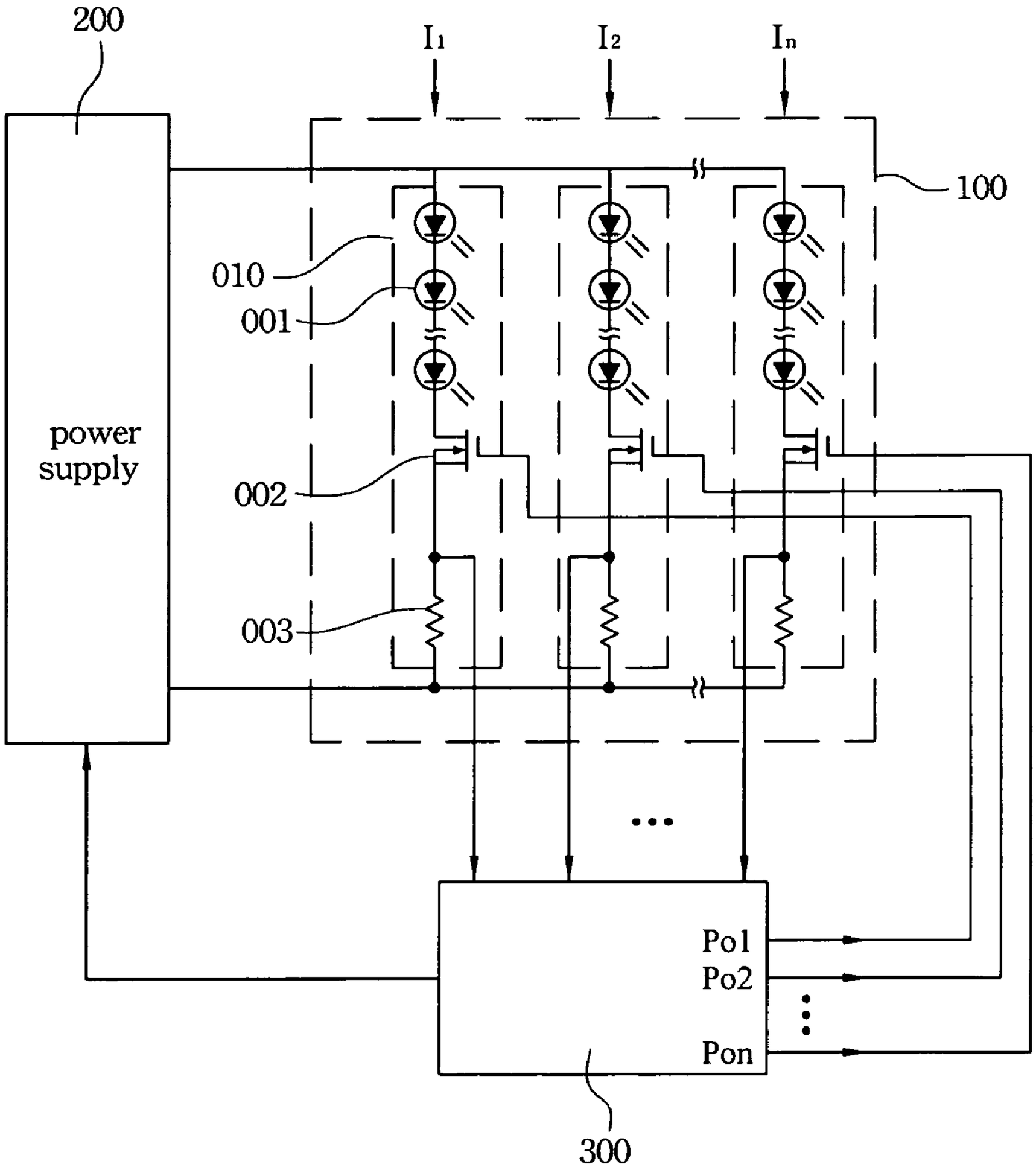


FIG. 2

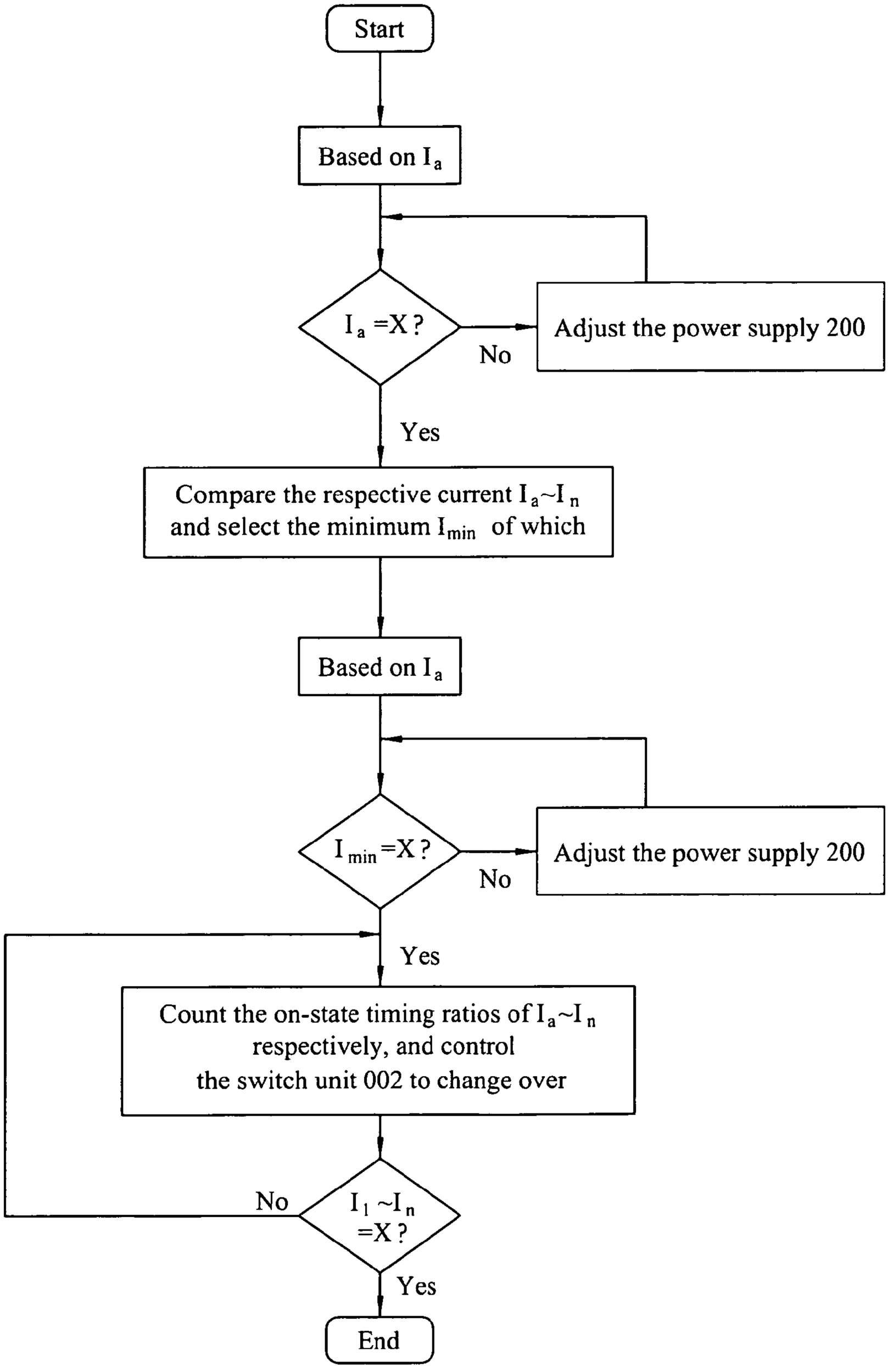

Start
Based on I_a
I_a =X ?
No
Adjust the power supply 200
Yes
Compare the respective current I_a~I_n and select the minimum I_{min} of which
Based on I_a
I_{min} =X ?
No
Adjust the power supply 200
Yes
Count the on-state timing ratios of I_a~I_n respectively, and control the switch unit 002 to change over
No
I_1 ~I_n =X ?
Yes
End

FIG. 3

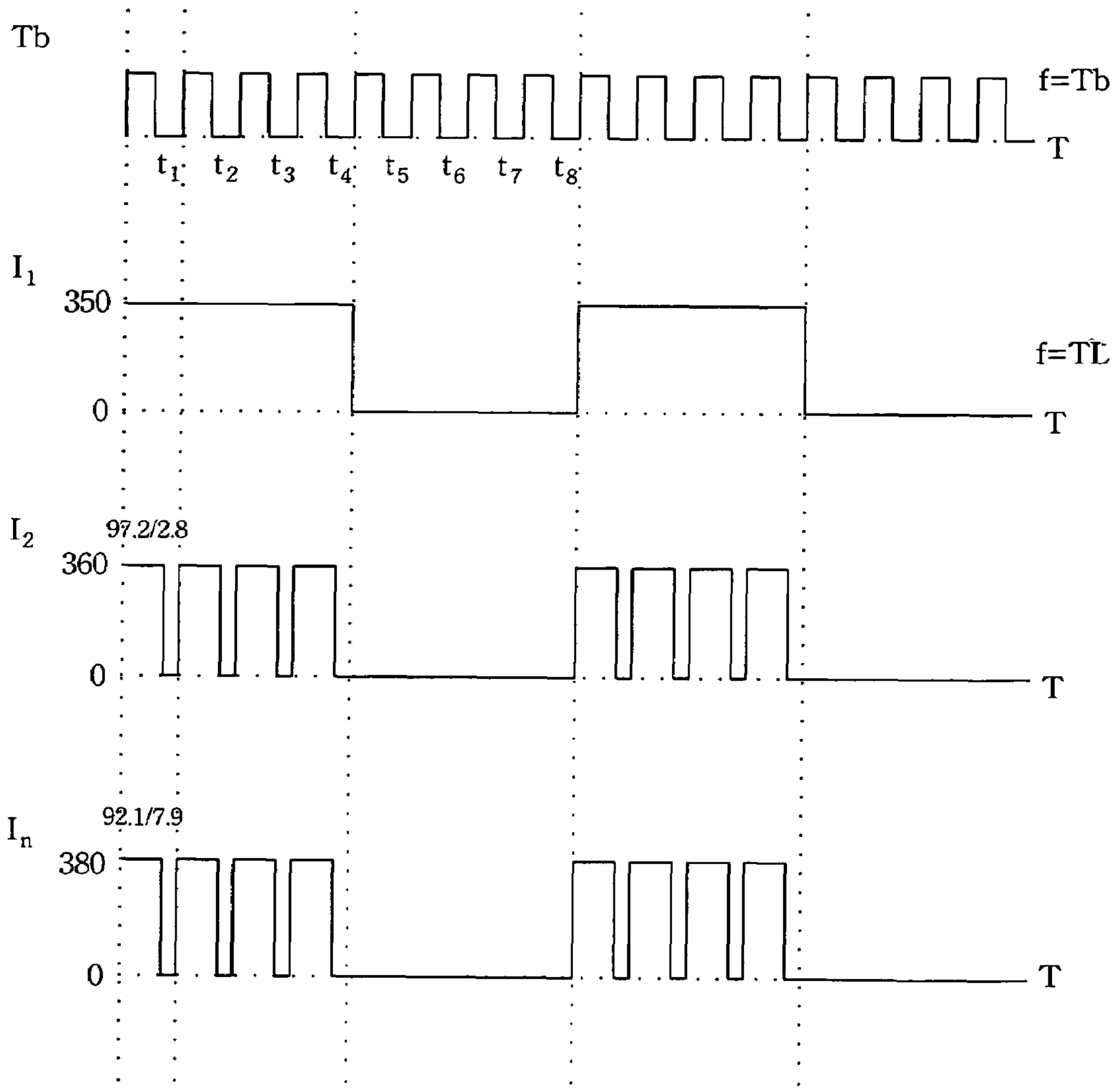

Tb
f=Tb
T
t1 t2 t3 t4 t5 t6 t7 t8
I1
350
0
f=TL
T
I2
97.2/2.8
360
0
T
In
92.1/7.9
380
0
T

FIG. 4

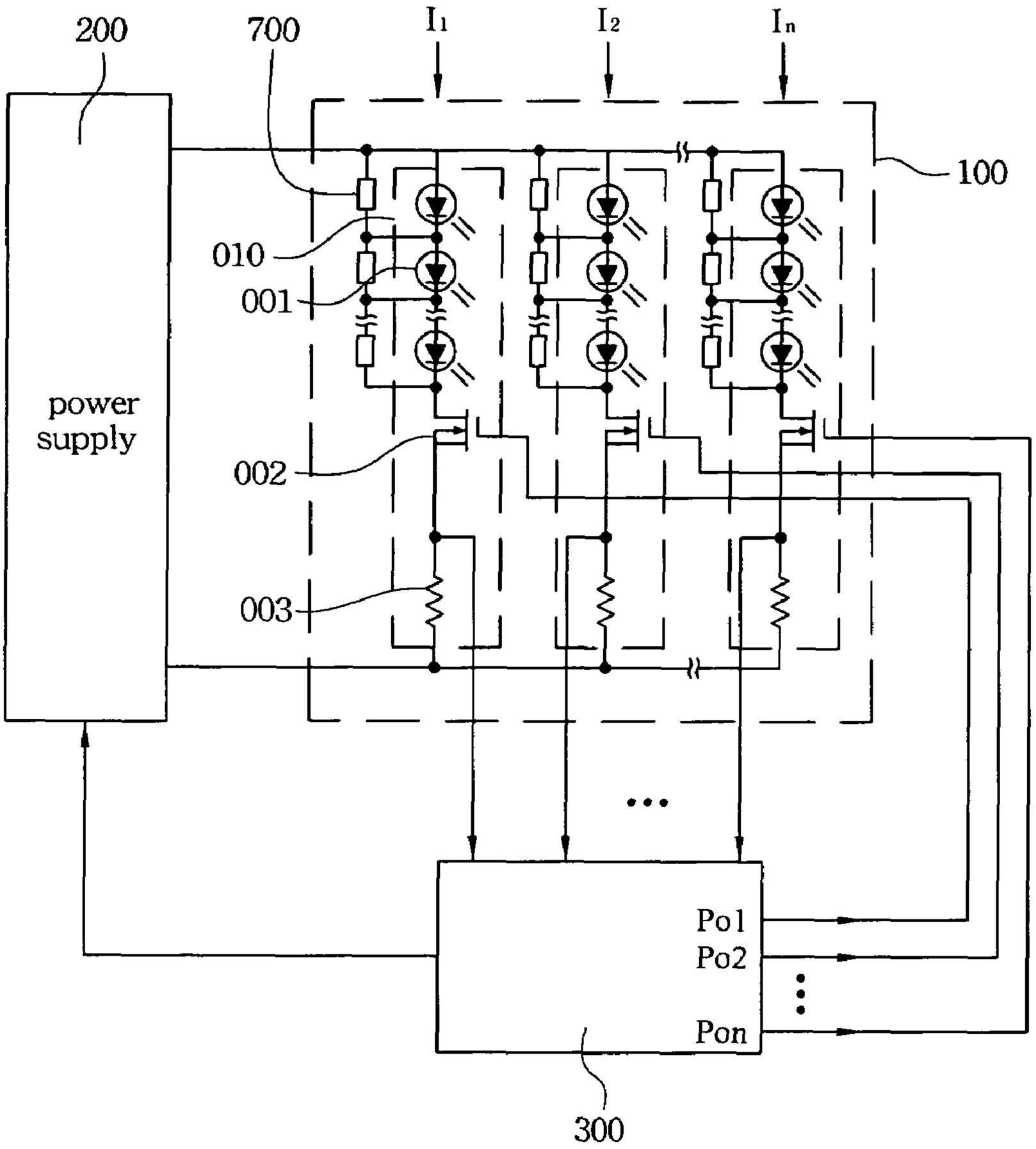

200
700
I1
I2
In
100
010
001
002
003
power supply
Po1
Po2
Pon
300

FIG. 5

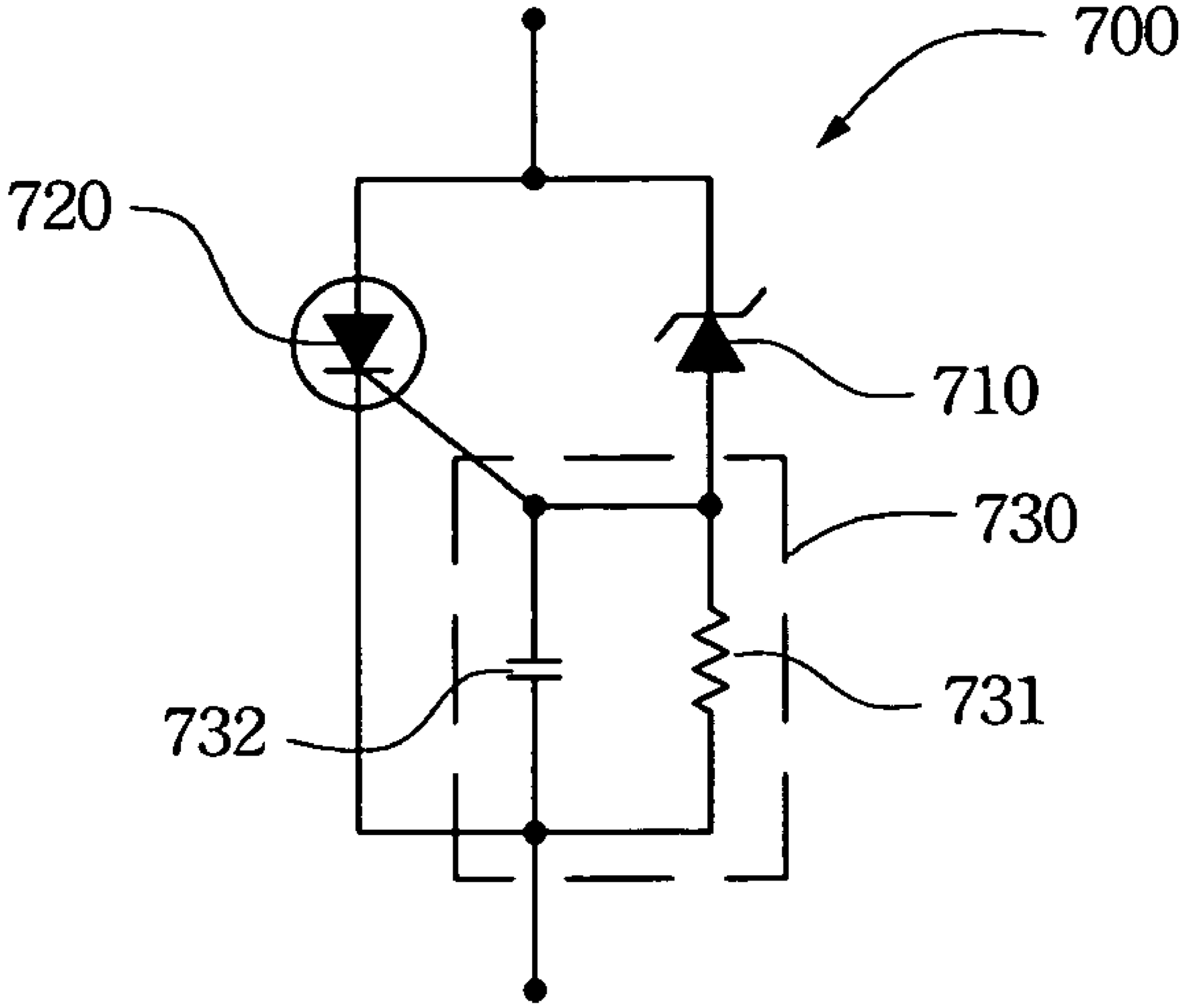


FIG. 6

CONTROL CIRCUIT FOR BALANCING CURRENT AND METHOD THEREOF

RELATED APPLICATIONS

The present application is based on, and claims priority from, Taiwan Application Serial Number 94113276, filed Apr. 26, 2005, the disclosure of which is hereby incorporated by reference herein in its entirety.

FIELD OF THE INVENTION

The present invention relates to a control circuit for balancing current, and more particularly, to a control circuit for balancing current of the light emitting diode (LED) of the light source in a thin display device.

BACKGROUND OF THE INVENTION

Reference is made to FIG. **1**, a light source is formed by a plurality of LED rows **010'** in parallel connection with each other in a conventional thin display device, in which the respective LED rows **010'** include at least one LED **001'** and an adjusting device **002'**. In order to make the thin display device to have uniform brightness on the screen, the conventional adjusting method usually adjusts the currents of the respective LED rows **010'** to be the same. The adjusting device **002'** adjusts an impedance value to make the respective LED rows **010'** to be the same, for achieving the state of current balance.

However, in such adjusting method, the adjusting device **002'** in series connection with the respective LED row **010'** consumes more power, and the total efficiency of the light source **100'** is relatively affected, too. Moreover, the impedance value adjusted by the adjusting device **002'** is the default set in the production, and the default is different to be adjusted after assembling. The change of the impedance value depends on the influence of external factors, such as temperature and humidity thereby affecting the current balance of the respective LED rows **010'**.

In addition, in order to match a rapid change of an image for the thin display device, the light source blinks and turns off transiently in a frequency of persistence of vision of human eyes, for preventing image-sticking phenomenon on the screen. The respective LED rows **010'** in the conventional light source **100'** are directly connected with the power supply **200'**. An output capacitance usually exists in the power supply **200'**. After the power is cut off, the power is continuously provided until the output capacitance finishes discharging. It results that the light source **100'** fades away to decrease luminance gradually when the light source **100'** is turned off. Consequently, light source **100'** causes image-sticking phenomenon on the screen.

Moreover, the respective LED rows comprise a plurality of LEDs **001'** in series connection. If any LED **001'** of the LED row **010'** is broken to form an open circuit, such LED row **010'** cannot work.

SUMMARY OF THE INVENTION

It is an aspect of the present invention to provide a control circuit for balancing current, which controls the current balance of the respective LED row of the light source in a thin display device anytime and continuously.

It is another aspect of the present invention to provide a control circuit for balancing current, which enables the LED to blink and turn off transiently for preventing image-sticking phenomenon on the screen.

It is a further aspect of the present invention to provide a control circuit for balancing current, even though one of the LEDs is broken which enables the other LEDs operating normally and continuously, and simultaneously controls the current balance of the respective LED row.

According to the aforementioned aspect of the present invention, a control circuit for balancing current is provided, which is employed in a thin display device. The control circuit for balancing current comprises a light source, a power supply and a control part. The light source includes a plurality of parallel LED rows, wherein each of the LED rows includes at least one LED and a first switch unit. The first switch unit is in series connection with the LED, for determining whether a current passes through each of the LED rows according to on/off two states. The power supply provides the LEDs with a working power. The control part detects the current of the LED rows, controls an on-state timing ratio of the first switch units, and controls an output power of the power supply.

In a preferred embodiment of the present invention, the each of LED rows further includes a current-limiting device in series connection with the LED and the first switch unit, for limiting the current of each of the LED rows.

In a preferred embodiment of the present invention, the control circuit for balancing current further comprises a short circuit connected in parallel with the LED for connecting two ends of an open circuit caused by a broken LED. The short circuit comprises a trigger part and a second switch unit. The trigger part detects the open circuit caused by the broken LED, and then triggers the second switch unit to be at an on-state for connecting the two ends of the open circuit. The short circuit further comprises a safety device in series connection with the trigger part. The safety device includes a wave-filtering part and a current-limiting part. The wave-filtering part is employed to filter a noise signal passed through the trigger part for preventing a mistaken operation of the trigger part. The current-limiting part connects in parallel with the wave-filtering part, and the current-limiting part is employed to limit the current passed through the trigger part.

In a preferred embodiment of the present invention, the control part generates a reference timing pulse for control the on-state timing ratios of the first switch units according to the reference timing pulse.

According to the aforementioned aspect of the present invention, a controlling method for balancing current is further provided, which is employed to balance currents of a plurality of parallel LED rows in a thin display device. At first, a current of anyone of the LED rows is increased to a predetermined working current. Next, a minimum current of the currents of the LED rows is selected. And then, the minimum current is increased to the predetermined working current. Afterwards, an on-state timing ratio of a current of each of the LED rows is counted, and the currents of the LED rows change according to the on-state timing ratio.

In a preferred embodiment of the present invention, the controlling method for balancing current further comprises cutting off a power supply when the current of anyone of the LED rows is detected to be zero.

In a preferred embodiment of the present invention, the controlling method for balancing current further comprises connecting an open circuit caused by a broken LED of the LED rows.

In a preferred embodiment of the present invention, the controlling method for balancing current further comprises making the LED rows to be opened when the current of anyone of the LED rows is detected to be increased abnormally. Afterwards, detection of the current of the LED rows is skipped or a power supply is cut off.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing aspects and many of the attendant advantages of this invention will become more readily appreciated as the same becomes better understood by reference to the following detailed description, when taken in conjunction with the accompanying drawings, wherein:

FIG. **1** depicts a diagram of the control circuit for balancing current in the prior art;

FIG. **2** depicts a diagram of the control circuit for balancing current of the present invention;

FIG. **3** depicts an operation flow chart of the present invention;

FIG. **4** depicts a timing diagram;

FIG. **5** depicts a circuit diagram of the control circuit for balancing current according to an implemented embodiment; and

FIG. **6** depicts a circuit diagram of the short circuit according to a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Hereinafter, the spirit of the present invention is more explicitly and completely clarified with reference to the following figures. After the preferred embodiments of the present invention is understood by a person skilled in the art, various modifications and similar arrangements can be made according to the skill taught by the present invention and be included within the spirit and scope of the present invention.

Reference is made to FIG. **2**, the control circuit for balancing current of the present invention is employed to adjust the current balance of the respective LED row of a light source in a thin display device. The control circuit for balancing current comprises a light source **100**, a power supply **200** and a control part **300**.

The light source **100** includes a plurality of parallel LED rows **010**, wherein each of the LED rows **010** comprises at least one LED **001** and a first switch unit **002**. The LED **001** is in series connection with the switch unit **002**. The LED **001** is employed to irradiate and illuminate, and the switch unit **002** is employed to determine whether a current passes through each of the LED rows **010** according to on/off two states, that is to say, to determine whether the LED **001** is turned on/off. The switch unit **002** is a device of, for example, a semiconductor transistor, a metal-oxide semiconductor field-effect transistor (MOSFET) and the like.

The power supply **200** is in series connection with the light source **100** for providing the respective LED **001** with a working power.

The control part **300** receives currents I_1 to I_n, of the respective LED row **010**, detects whether the currents I_1 to I_n are the same, controls an on-state timing ratio of the switch units **002** on the basis of the currents I_1 to I_n, and controls an output power of the power supply **200**.

The LED rows **010** further includes at least one current-limiting device **003**, which is in series connection with the LED **001** and the switch unit **002** for limiting the current of each of the LED rows **010**. The current-limiting device **003** is, for example, a resistor.

Please refer to FIGS. **2**, **3**, and, **4**. The control circuit for balancing current of the present invention corresponds to the current value of the respective LED row **010**. The control part **300** is employed to control an on-state timing ratio of the switch unit **002** of the respective LED row **010**, thereby converting the current passed through the respective LED row **010** into pulses having appropriate on-state timing ratio. The current of the respective LED row **010** is adjusted to perform a light modulation of pulse width modulation (PWM).

At first, a working current value X of each LED rows **010** and a blinking frequency TL of each LED **001** are predetermined. The blinking frequency TL is higher than a frequency of persistence of vision of human eyes.

The control part **300** controls the switch unit **002** to quickly convert the current passed through each LED rows **010** into a power source as the frequency TL.

Based on the current I_a of one LED row **010**, the power supply **200** controlled by the control part **300** outputs a power source to make I_a to achieve the predetermined working current value X.

The currents I_1 to I_n are compared with each other, and the minimum I_{min} of which is found out.

Based on the minimum I_{min}, the power supply **200** controlled by the control part **300** outputs another power source for promoting the minimum I_{min} to the predetermined working current value X.

When the original minimum I_{min} is increased to the predetermined working current value X, currents of other LED rows are increased to be more than the working current value X because of the raised power source.

At this time, the on-state timing ratio of the switch unit **002** of the respective LED row **010**, i.e. the ratio of X to the respective current I_1 to I_n is counted. The switch unit **002** in series connection with the respective LED row **010** is controlled by the control part **300**, and the switch unit **002** converts the current of the respective LED row **010** into the pulses having appropriate on-state timing ratio.

The control part **300** receives the currents I_1 to I_n anytime and continuously, detects whether the currents I_1 to I_n are the same, controls an on-state timing ratio of the respective switch units **002** on the basis of the currents I_1 to I_n, and controls an output power of the power supply **200** for maintaining the balance of the currents I_1 to I_n.

In addition, as any broken LED **001** causes an open circuit, no current passes through such LED row **010** and the current value is zero. As the control part **300** detects that the current of any LED row **010** is zero, the control part **300** sends a signal to cut off power supplying of the power supply **200**. It prevents severer damage caused by the abnormal current values of other LED rows **010** that results from the control part **300** setting the current value of the open-circuited LED row **010** as the minimum I_{min} to raise power supplying of the power supply **200** unlimitedly.

Besides, when the current of the LED row **010** is abnormally higher than the predetermined working current value X, at this time, the control part **300** controls the switch unit **002** to cut off for forming an open circuit, so that it prevents the abnormally high current from destroying the control part **300**. While the switch unit **002** is cutting off for forming an open circuit, the current value of the LED row **010** is zero. In order to prevent severer damage caused by the abnormal current values of other LED rows **010** that results from the control part **300** setting the current value of the open-circuited LED row **010** as the minimum I_{min} to raise power supplying of the power supply **200** unlimitedly, in the meantime that the switch unit **002** cuts off for forming the open circuit, the control part **300** sends a signal to skip the detection of the current of the LED row **010** and to continue the normal operation of other LED rows **010**. Alternatively, the control part **300** sends a signal to cut off power supplying of the power supply **200**.

Reference is made to FIG. **4**, if the predetermined working current value X is 350 mA and the blinking frequency of the LED is TL, the control part **300** generates a reference timing

pulse Tb. If the current I_1 is 350 mA, the current I_2 is 360 mA, and the current I_n is 380 mA, relative to the reference timing pulse Tb, the control part **200** controls the switch unit **002** of the LED row **010** of the current I_1 according to the frequency TL, so the current I_1 is kept as a pulse of 350 mA and the frequency TL.

The ratio of the predetermined working current value X to the current 1_2, i.e. 360 divided by 380, is approximately 97.2 percent. Therefore, when the current I_2 of the frequency TL is in the Hi condition, relative to the reference timing pulse Tb, the control part **200** further controls the switch unit **002** of the LED row **010** of the current I_2 to convert according to 97.2 percent of the on-state timing ratio, so the current I_2 at the frequency TL in the Hi condition is converted into a pulse of 97.2 percent of the on-state timing ratio.

In the same way, the ratio of the predetermined working current value X to the current I_n, i.e. 350 divided by 380, is approximately 92.1 percent. Therefore, when the current I_n of the frequency TL is in the Hi condition, relative to the reference timing pulse Tb, the control part **200** further controls the switch unit **002** of the LED row **010** of the current I_n to convert according to 92.1 percent of the on-state timing ratio, so the current I_n at the frequency TL in the Hi condition is converted into a pulse of 92.1 percent of the on-state timing ratio.

Accordingly, the currents I_2 and I_n are controlled to be the same as the predetermined working current value X.

As the current of the respective LED row is in the condition that the pulse is zero, it means that the control part **200** controls the switch unit **002** to be in a cut-off and opened-circuit state. The power supply **200** cannot supply power to the respective LED row **010**, at this time, the respective LED is turned off.

The operation of balancing currents proceeds anytime and continuously. Hence, when some external factors, such as temperature, humidity and the like, cause the circuit resistance to change, the currents of the circuit are also adjusted anytime and continuously.

Because the respective LED **001** and the respective current-limiting device **003** utilize the same settings, the difference between the above two is much less. Moreover, the blinking frequency TL for controlling the respective LED **001** is further higher than the frequency of persistence of vision of human eye, and the converted pulses of appropriate on-state timing ratio according to the reference timing pulse Th is equal to or more than the frequency TL. Thus, human eyes do not feel the light source unevenness or blinks resulted from the different on-state times of the LED rows **010**. Instead, the LED rows **010** are controlled at the same current respectively to have the same brightness.

Also, the on/off two states of the switch unit **002** determine whether the current passes through the LED row **010**, and no output capacitor exists. After cutting off the switch unit **002**, the LED row **010** immediately exhibits an opened state, so that the LED **001** is transiently turning off while the switch unit **002** is cutting off.

Various applications and practices can be carried out within the scope of the technical thought of the present invention. Reference is made to FIG. **5**, which is a circuit for balancing currents including a plurality of short circuits **700**. The short circuits **700** are connected in parallel with the respective LEDs **001** for connecting two ends of an open circuit caused by a broken LED, so that other unbroken LEDs **001** of the same LED row **010** can continue to operate. When the short circuit **700** operates, the change of the current depends on the change of the impedance value of the LED row **010**. At this time, the above method for balancing current is repeated to adjusted the current to the predetermined working current value X.

FIG. **6** depicts an embodiment of the short circuit **700**, which includes a trigger part **710** and a second switch unit **720**. When the LED **001** operates normally, the end voltage of the LED **001** keeps at a normally working voltage. When the LED **001** is broken to form an open circuit, the end voltage of the LED **001** is increased to be an output voltage of the power supply **200**. At this time, the trigger part operates due to the raised voltage, and triggers the switch unit **720** to be at on state for replacing the broken and open-circuited LED **001**, so that the power supply **200** provides unbroken LEDs **001** of the LED row **010** with current.

The aforementioned trigger part **710** is, for example, a zener diode or the like. The switch unit **720** is, for example, a transistor, or a SCR (Silicon Controlled Rectifier), TRIAC (Bidirectional Triode Thyristor) or the like thyristor in the electronic devices of the circuit industry. The short circuit **700** further includes a safety device **730** in series connection with the trigger part **710**. The safety device includes a wave-filtering part **731** and a current-limiting part **732**. The current-limiting part **731** connects in parallel with the wave-filtering part **732**. The current-limiting part **731** is employed to limit the current passed through the trigger part **710**. The wave-filtering part **732** is employed to filter a noise signal passed through the trigger part **710** for preventing a mistaken operation of the trigger part **710**. The current-limiting part **731** is, for example, a resistor. The wave-filtering part **732** is for example, a capacitor.

When all LEDs **001** of the same LED row **010** are broken, the respective short circuits **700** are at on state, so that the current of the LED row **010** is abnormally higher than the predetermined working current value X. At the moment, the control part **300** cuts off the switch unit **002** of the LED row **010** to form an open circuit, for preventing the control part **300** from being destroyed by the abnormally high current. While the switch unit **002** is cutting off for forming an open circuit, the current value of the LED row **010** is zero. In order to prevent severer damage caused by the abnormal current values of other LED rows **010** that results from the control part **300** setting the current value of the open-circuited LED row **010** as the minimum I_{min} to raise power supplying of the power supply **200** unlimitedly, in the meantime that the switch unit **002** cuts off for forming the open circuit, the control part **300** sends a signal to skip the detection of the current of the LED row **010** and to continue the normal operation of other LED rows **010**. Alternatively, the control part **300** sends a signal to cut off power supplying of the power supply **200**.

Even though the short circuit is illustrated with an embodiment of FIG. **6** in the specification, the short circuit is not limited by the circuit depicted in FIG. **6**. However, any circuit, which can connect in parallel with the respective LED, connect two ends of an open circuit caused by a broken LED and make the current to pass through, should be included within the scope of the present invention.

The timing diagram of FIG. **4** shows that the reference timing pulse Tb is eight-fold of the blinking frequency TL of the LED. However, the reference timing pulse Tb is not limited by being eight-fold of the blinking frequency TL of the LED. Any reference timing pulse Tb capable of being included within the scope of the present invention, which makes the current pulses of the respective LED rows that are more than the predetermined working current value X to be in Hi condition and to be appropriate on-state timing ratios of pulses based on the reference timing pulse Th, so that the

currents of the respective LED rows are balanced. The reference timing pulse Tb includes a frequency equal to or more than the blinking frequency TL of the LED.

According to the aforementioned preferred embodiments, advantages of the present invention is as follows:

1. The control part controls the current balance of the respective LED row of the light source in a thin display device anytime and continuously. That is to say, even though external factors cause changes in the currents of the respective LED rows, the control part can automatically adjust and keep the balance of the currents.
2. The switch part enables the LED to blink and turn off transiently for preventing image-sticking phenomenon on the screen.
3. The short circuits are connected in parallel with the respective LEDs. Even though any LED is broken, other LEDs can operate normally and continuously. Moreover, the control part controls the respective LED rows continuously to keep the balance of the currents.

As is understood by a person skilled in the art, the foregoing preferred embodiments of the present invention are illustrated of the present invention rather than limiting of the present invention. It is intended that various modifications and similar arrangements should be included within the spirit and scope of the appended claims, the scope of which should be accorded the broadest interpretation so as to encompass all such modifications and similar structure.

What is claimed is:

1. A control circuit for balancing current, employed in a thin display, comprising:

a light source, which includes a plurality of parallel light-emitting diode (LED) rows, wherein each of the LED rows includes:

at least one LED; and

a first switch unit that is in series connection with the LED for determining whether a current passes through each of the LED rows;

a power supply that is in series connection with the light source for providing the LEDs with a working power;

a control part that detects the current of the LED rows, controls an on-state timing ratio of the first switch unit, and controls an output power of the power supply; and

a short circuit connected in parallel with the LED for connecting two ends of an open circuit caused by a broken LED, wherein the short circuit comprises:

a trigger part; and

a second switch unit, wherein the trigger part detects the open circuit caused by the broken LED, and then the trigger part triggers the second switch unit to be at on-state for connecting the two ends of the open circuit.

2. The control circuit for balancing current according to claim **1**, wherein each of the LED rows further includes a current-limiting device being in series connection with the LED and the first switch unit for limiting the current of each of the LED rows.

3. The control circuit for balancing current according to claim **1**, wherein the short circuit further comprises a safety device being in series connection with the trigger part, the safety device includes:

a wave-filtering part employed to filter a noise signal passed through the trigger part for preventing a mistaken operation of the trigger part; and

a current-limiting part connecting in parallel with the wave-filtering part, wherein the current-limiting part is employed to limit the current passed through the trigger part.

4. The control circuit for balancing current according to claim **1**, wherein the control part generates a reference timing pulse for controlling an on-state timing ratios of the first switch unit according to the reference timing pulse.

5. A controlling method for balancing current, employed to balance currents of a plurality of parallel LED rows in a thin display device, comprising:

increasing one of currents of the LED rows to a predetermined working current;

selecting a minimum current of the currents of the LED rows;

increasing the minimum current to the predetermined working current; and

counting an on-state timing ratio of a current of each LED rows, and changing the currents of the LED rows according to the on-state timing ratio.

6. The controlling method for balancing current according to claim **5**, further comprising cutting off a power supply when the current of anyone of the LED rows is detected to be zero.

7. The controlling method for balancing current according to claim **5**, further comprising connecting an open circuit caused by a broken LED of the LED rows.

8. The controlling method for balancing current according to claim **5**, further comprising:

making the LED rows to be opened when the current of anyone of the LED rows is detected to be increased abnormally; and

skipping detection of the current of the LED rows.

9. The controlling method for balancing current according to claim **5**, further comprising cutting off a power supply when one of the currents of the LED rows is detected to be increased abnormally.

* * * * *